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Native American Land-Use Practices and Ecological Impacts

ABSTRACT

During a span of 10,000 years or more, Native Americans in the Sierra Nevada were sustained by hunting and fishing, gathering, lithic quarrying, and trading. To meet their requirements for firewood, fish and game, vegetal foods, craft supplies, and building materials, the native peoples of the Sierra managed biotic resources intensively, with significant ecological and evolutionary consequences. The distribution, structure, composition, and extent of certain plant communities, for example, were shaped by burning, pruning, sowing, weeding, tilling, and selective harvesting. Numerous "protoagricultural" techniques, based upon traditional knowledge of natural processes gained over the millennia, were applied to increase the quantity and improve select qualities of focal plant species. Fire was the most important management tool, employed to clear brush, maintain grasslands and meadows, improve browse for deer, enhance production of basketry and cordage materials, modify understory species composition in forests, and reduce fuel accumulation that might otherwise sustain intense fires. Considering that the human population of the Sierra Nevada was approximately 90,000–100,000 in late prehistoric times (ca. A.D. 1300–1800), the environmental consequences of aboriginal land-use and management practices were substantial. There is currently an ecological "vacuum," or disequilibrium, in the Sierra resulting from the departure of Native American influences. The recent decline in biotic diversity, species extirpation and endangerment, human encroachment into fire-type plant communities (e.g., chaparral), and greatly increased risk of catastrophic fires are but symptoms of this disequilibrium. It is recommended, therefore, that land-managing agencies and land-use planners incorporate Native American traditional knowledge into future policies and programs for ecosystem management in the Sierra Nevada. This traditional knowledge, which permitted the adaptive success of large human populations and the maintenance of Sierran environments for more than a hundred centuries, must not be dismissed.

INTRODUCTION

Californians are faced with the growing necessity of finding ways to maintain the integrity and livability of their ecosystems (Barbour et al. 1993; Jensen et al. 1993). Increasing knowledge of the diverse ecological relationships of native peoples to their environments affords an opportunity to assess these relationships with respect to ecological principles and to assess their value for helping to solve regional and local environmental problems (Nabhan 1995). Sustainability is increasingly being defined in terms of conserving cultural as well as biological diversity (Manley et al. 1995). The varied past approaches of Native Americans to resource use and management in the Sierra Nevada could contribute significantly to maintaining biological and cultural diversity, and improving human livelihood (Soulé and Kohm 1989). Resource management by Native Americans in the Sierra Nevada bioregion was long term and widespread, producing ecological and evolutionary consequences in the biota (Blackburn and Anderson 1993). Therefore, many ecosystems in the Sierra are not self-maintaining islands that require only protection to remain in a "pristine" state. There is currently an

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ecological "vacuum," or disequilibrium, in the Sierra Nevada resulting from the departure of Native Americans from managing these ecosystems.

This chapter explores why present-day management and restoration of the Sierra Nevada bioregion should be grounded in historical as well as ecological research. It provides an overview of the Native Americans who inhabited the Sierra Nevada during the early 1800s as well as those who live there today, their land-use activities, management practices, environmental ethics, and potential beneficial and negative ecological effects in different ecosystem types. Also, it asks a series of questions about the state of knowledge and substantiated evidence for modification of Sierran landscapes by indigenous peoples. Specific examples of production systems for three cultural use categories—basketry, foods, and cordage—are given. Ecological consequences of removing Native Americans from traditional economic and land-management roles in the Sierra Nevada are examined, and an agenda for future policy, research, and management directions as well as collaborative efforts with contemporary Native Americans is proposed.

Relevance of Native American Environmental History to Sierra Nevada Ecosystem Project Objectives

Knowledge of the history of natural systems is an essential component of scientific analysis (Crumley 1994; Smith 1994). This history influences our ability to assess the present health and condition of ecosystems in the Sierra Nevada and to predict the future (Woolfenden 1994). Plant-community organization and assemblages are expressions of species evolution and species behavior (Whittaker and Woodwell 1972), and plant adaptations are responses to past environmental conditions. Native Americans, as integral residents of the Sierra Nevada, modified environmental conditions, dispersed plant species to new areas, and created recent evolutionary modifications in the flora through human selection for particular traits. Thus, Native Americans were instigators of ecosystemic change with varying degrees of intensity during the time they inhabited the Sierra, beginning some 10,000 years ago (Elston et al. 1977; Moratto 1984; Moratto et al. 1988; Peak and Crew 1990; Rondeau 1982).

The Sierra Nevada did not fit the definition of an uninhabited, virgin wilderness at the point of Euro-American contact. Rather, it had been shaped by thousands of years of indigenous burning, pruning, sowing, selective harvesting, and tilling (Anderson and Nabhan 1991; Simms 1992). Native Americans have managed Sierran ecosystems in a nonrandom fashion, using a variety of horticultural techniques. Such management is substantiated by ethnohistoric and ethnographic records, studies of museum artifacts, paleoecological findings, fire scar studies, and ecological field studies (Anderson 1993b; Anderson and Carpenter 1991; Kilgore and Taylor 1979; Lewis 1993; Matson 1972; Roper Wickstrom 1987). Furthermore, early humans were effective hunters, influencing the distribution, abundance, and diversity of wildlife within their tribal territories. To understand the vegetation of a particular locality or region at a specific time requires knowledge of soil, topography, climate, natural processes, and history of land use by Native Americans.

We are in the first stages of documenting in a detailed and intensive manner the prehistoric and historic land-management practices in the Sierra Nevada. Deliberate management of wild plant and animal resources and habitats was a major element of Native American subsistence strategies. Yet, investigation of the relationships between such land-management activities and their ecological consequences is a nascent field of study. In fact, there exists no synthesis or detailed analysis of past wildlife management by Native Americans and its potential ecological impacts in the Sierra Nevada. It is clear that Native American land-management practices had significant ecological and evolutionary consequences on the biota, but the details of these impacts will remain unknown for specific geographic regions until interdisciplinary teams conduct more comprehensive studies.

If the goal of public land-managing agencies is to preserve certain ecosystems in some semblance of their pre-contact structures and functions, then they can no longer ignore these anthropogenic effects and must investigate the possibility of simulating some of the earlier cultural practices (Anderson 1993a; Wagner et al. 1995). The most recent argument against using pre-contact vegetation as a baseline for contemporary wildland management is that it would be treating ecosystems as "living museums" rather than as dynamic systems. This argument holds that wilderness areas should be treated as places where nonhuman life and ecological processes are unimpeded (Parsons et al. 1986). Yet pre-Euro-American vegetation was far from fixed. The underlying management philosophy of Native Americans in the Sierra Nevada was to continuously introduce small disturbance regimes into various plant-community types, which created openings or clearings. These openings invited the colonization of plant species that could not grow in the surrounding dominant vegetation type. These clearings represented a series of earlier successional stages within a more homogeneous landscape. Rather than reflecting an unchanging system, these landscapes were much more dynamic under the influence of human disturbance than in their "natural" state.

The nature and intensity of human intervention varied both geographically and diachronically. For example, some areas were subject only to lightning fires; other areas experienced both lightning- and Indian-set fires; and yet other areas were shaped largely by anthropogenic forces (i.e., frequent Indian-set fires). The creation of specialized habitats intensified plant-plant, plant-animal, animal-animal, human-animal, and human-plant relationships, creating a highly interactive system that ultimately changed vegetation patterns over time. Hence, the objective is not to re-create exactly a static picture of historic landscapes, but rather to investigate and understand the native cultural processes that drove biological diversity and shaped various ecosystem states and to unravel the ecological principles embedded in ancient land-management systems. As Christensen (1988) has recognized, diverse disturbances play an essential role in the long-term maintenance of virtually all ecosystems.

The Study of Native American Land-Management Practices

Analysis of indigenous protoagricultural practices yields a baseline of historical ecological information about the diversity, dynamics, and functioning of plant communities in the Sierra Nevada under former disturbance regimes. It also offers other models of human cultural intervention in nature. Simulating some of these practices in long-term field experiments would elucidate the effects of aboriginal activities upon natural resources in the Sierra Nevada and disclose the extent to which ecosystem health in the areas of soil productivity, gene conservation, biodiversity, landscape patterns, nutrient cycling, and an array of ecological processes is tied to former native economic and management activities. Native Americans have influenced Sierran landscapes over many generations. Their traditional knowledge of former abundances, composition, density, and quality of plant and animal species extends to time periods long before the advent of governmental land management. Their land-use practices were successful for thousands of years in maintaining diverse and productive ecosystems. The time depth of this traditional knowledge may provide a sense of what has been lost in Sierran landscapes since aboriginal times. Contemporary native cultures still maintain some of the traditional practices, and these may serve as analogs for testing alternative wildland-management strategies, restoring endangered ecosystems and species, enhancing the productivity and biodiversity of wildlands, and maintaining culturally significant plant resources for the perpetuation of native cultural traditions (Birckhead et al. 1992; Martinez 1992). If ecologists and land managers could understand the intricacies and mechanics of how and why native people shaped ecosystems, it would enrich their inventory of management methods and enhance their ability to make informed decisions.

OVERVIEW: PRE-CONTACT NATIVE AMERICAN INTERVENTIONIST APPROACH TO NATURE

Indian Tribes of the Sierra Nevada

There were numerous, distinctive cultures in the Sierra Nevada at the time of historic contact. During the early 1800s, this region was inhabited by approximately thirteen "tribes" (ethnic groups speaking separate languages) composed of many "tribelets" (Kroeber 1962). This variety of cultures was reflected in diverse adaptations to Sierran environments and myriad land-use and resource-management strategies. Tribes on the west side of the Sierra included the Maidu, Konkow, Nisenan, Northern Sierra Miwok, Central Sierra Miwok, Southern Sierra Miwok, Foothill Yokuts (Poso Creek, Tule-Kaweah, Kings River, and Northern Hill), Western Mono (Monache), and Tübatulabal; on the east side of the mountains were the Northern Paiute, Washoe, and Owens Valley Paiute; the Kawaiisu (and to some extent, the Washoe) held land on both sides of the range (figure 9.1).

Maidu lands included the Susan River, the Red Clover, Valley Indian, and Willow Creeks, and the upper stretches of the North Fork of the Feather River, while the Konkow occupied the watersheds of the Middle and South Forks of the Feather River and the lower stretches of the North Fork of the Feather River (Riddell 1978). The Nisenan inhabited the drainages of the Yuba, Bear, and American Rivers and the lowest reaches of the Feather River; they moved seasonally to higher elevations (Wilson and Towne 1978). The Sierra Miwok (or Me-Wuk) comprised three divisions: the Northern Sierra Miwok occupied foothills and mountains of the Mokelumne and Calaveras River drainages; the Central Sierra Miwok claimed the foothill and upland portions of the Stanislaus and Tuolumne watersheds; and the territory of the Southern Sierra Miwok embraced the upper reaches of the Merced and Chowchilla Rivers (Levy 1978). The Foothill Yokuts (or Northern Hill Yokuts) occupied the foothills from the Fresno River basin southward to the Kern River (Spier 1978a). At higher elevations were the Western Mono (Monache), with six geographic subdivisions: the Northfork Mono, Wobonuch, Entimbich, Michahay, Waksachi, and Patwisha (Spier 1978b). In the southern Sierra Nevada foothills, the Tübatulabal occupied the Kern and South Fork of the Kern River country; three Tübatulabal bands are recognized: Pahkanapïl, Palagewan, and Bankalachi (Smith 1978).

Portions of the eastern Sierra were inhabited by the Northern Paiute, Owens Valley Paiute, and Kawaiisu (figure 9.1). The Northern Paiute occupied a vast territory extending from the Sierran crest eastward to Reese River and from Mono Lake northward to the Snake River country (Fowler and Liljeblad 1986). Bordering the Northern Paiute, south of Mono Lake, the Owens Valley Paiute inhabited Owens, Round, and Long Valleys, and frequented the White and Inyo Mountains as well as the eastern slopes and crestal zone of the Sierra Nevada to obtain seasonal resources (Liljeblad and Fowler 1986). The Kawaiisu homeland was in the southeastern Sierra Nevada and adjacent portions of the Tehachapi and Piute Mountains. Settlements were focused along the Kern and South Fork of the Kern Rivers, with seasonal use of the Sierra Nevada foothills from Kelso Valley up through the Walker Pass locality (Zigmond 1981, 1986). The Washoe, linguistically unrelated to their Paiute neighbors, held the Lake Tahoe Basin, a series

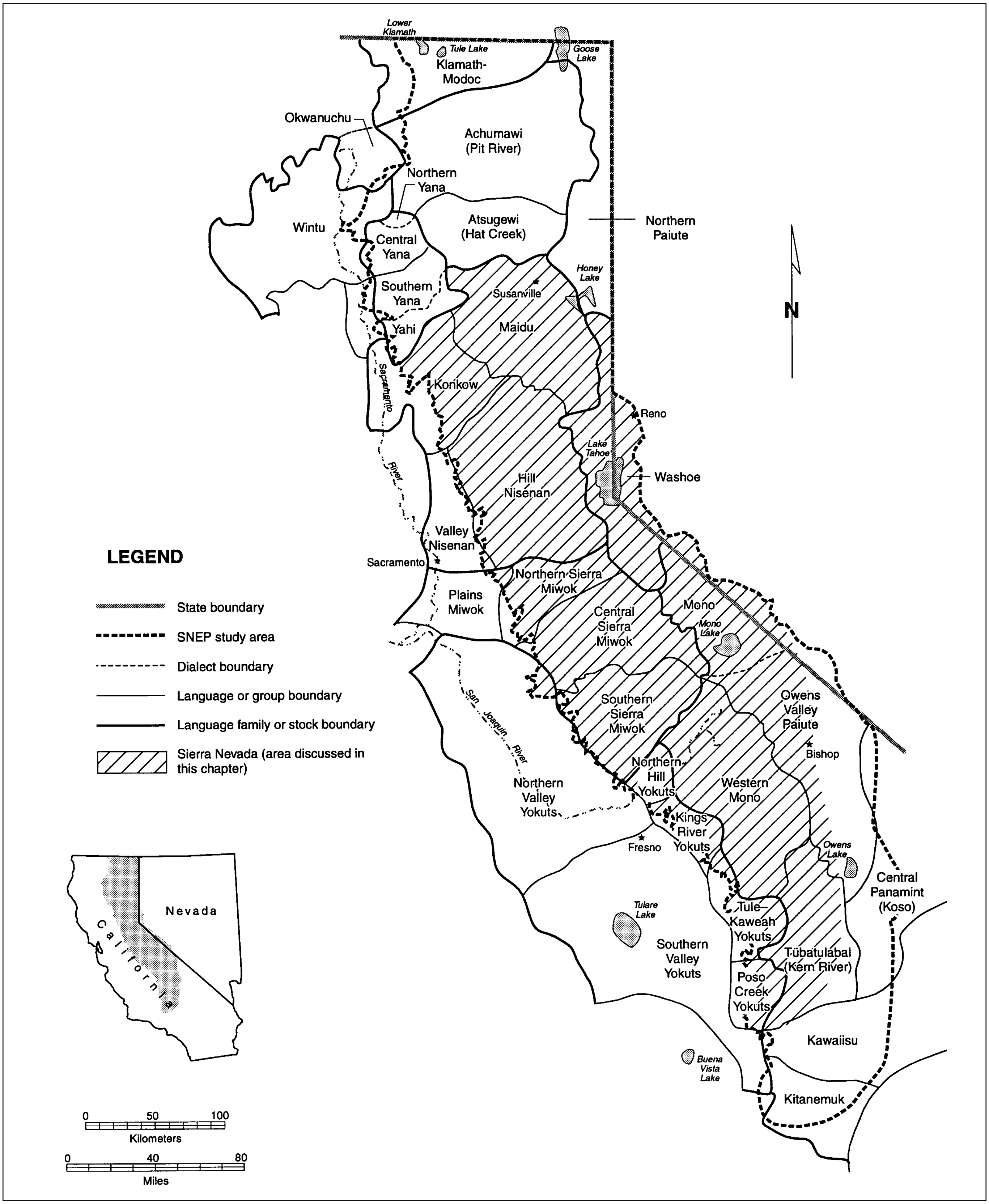

FIGURE 9.1

Tribal territories in the Sierra Nevada and adjacent regions, ca. A.D. 1800.

of montane valleys accented by Honey Lake, Washoe Lake, and Topaz Lake, and diverse biotic zones on the arid lands east of the Sierran crest, below Lake Tahoe (d'Azevedo 1986).

Native American Populations

The distribution of Native American populations in the Sierra Nevada was greatly influenced by environmental and cultural factors. On a regional scale, population densities were highest and "permanent" settlements most frequent at elevations below 1,000–1,250 m (3,300–4,100 ft); higher-altitude sites typically were occupied mostly during the warm season. Population densities tended to be substantially higher on the western side of the range than along the Great Basin rim, east of the Sierran crest. Within these broad patterns, populations were geographically diverse. In each locality such variables as terrain, biotic diversity and richness, availability of water, and access to toolstone, as well as the traditional land-use practices of the local society, affected carrying capacity of the land and thus human population levels. On a micro scale, the siting of individual camps or villages reflected such considerations as view, aspect, slope, drainage, insolation, vegetative cover, protection from wind, avoidance of cold sinks, proximity to water and economic resources, outcrops of bedrock suitable for use as mills, nearby trails, perceived flood or fire hazards, and perhaps defense, as well as the intended site function, number of residents, anticipated duration of occupation, and proximity to other settlements.

The number of residents at particular sites ranged from a few (e.g., several men in a hunting camp) to a few hundred in the larger villages. Intermediate in size were seasonal and special-purpose encampments. Late prehistoric / protohistoric Sierran peoples often were organized into "village communities," each consisting of a named, principal village under a chief or headperson and a number of smaller, tributary settlements (Kroeber 1962; Merriam 1967). The central villages of such communities were often situated near major streams in favorable settings within the lower Transition and upper Sonoran life zones.

Any estimate of aboriginal (i.e., pre-A.D. 1800) populations in the Sierra Nevada must be framed by caveats. Population levels fluctuated over time in response to paleoenvironmental changes (Moratto et al. 1978, 1988); different methods of estimation (e.g., reliance on historical accounts, ethnographic recollections, or ecologic models) yield divergent results (cf. Baumhoff 1963; Cook 1976b; Kroeber 1925; Merriam 1905); and even such "accurate" historical documents as U.S. War Department and Office of Indian Affairs records from the 1850s may not be reliable indicators of earlier population levels. As S. F. Cook (1955a, 70) has noted,

> The depletion of population in the San Joaquin Valley [including the adjacent Sierra] between 1800 and 1850 was far greater than has been appreciated. . . . Warfare, massacre, forced conversion, starvation, and exposure all took a tremendous toll of life, but the sweeping epidemics of the 1830s were even more devastating [see Cook 1955b]. Together, these forces destroyed in the aggregate fully 75 per cent of the aboriginal population.

Taking into account a wide range of information from early Spanish, Mexican, and other historical sources, Cook (1955a) estimated aboriginal populations of 7,600 for the Kaweah River drainage, 3,500 for the Merced, 9,100 for the Kings, 19,000 for the Mariposa area, Chowchilla, Fresno, and upper San Joaquin Rivers, and 4,150 for the "foothill strip," including lands of the Central and Northern Miwok. This yields a subtotal of 43,350 people in the southwestern Sierra Nevada. In the northwestern Sierra, populations of 1,050 for the Mountain Maidu and 7,400 for the combined Hill Maidu (Konkow) and Nisenan are estimated (Cook 1976b), giving a subtotal of 8,450. Adding roughly 500 for the Northern Paiute, 1,500 for the Washoe, 1,000 for the Owens Valley Paiute, and 500 for the Kawaiisu (Kroeber 1925) yields 3,500 as a subtotal for the eastern Sierra. Taken together, these estimates total 55,300.

This total, however, may be substantially lower than the actual native population of the Sierra Nevada prior to ca. 1830. Some of the estimates may fall short of the mark because of reliance on postepidemic observations. Even so, several historical accounts refer to large populations: James D. Savage, who was involved with numerous Sierran tribes before the gold rush, estimated in 1851 that 50,000–55,000 Native Americans lived in the area between the Tuolumne and the Kern Rivers; O. M. Wozencraft, a U.S. Indian commissioner, in 1852 set the native population of the area between the Yuba and the Mokelumne Rivers at 40,000, noting that old residents said the number had been twice as large in 1848; and Indian agent Adam Johnson in 1853 estimated that Sierran and Central Valley Indians totaled 80,000 (Cook 1955a). Although Cook characterized these accounts as "broad generalizations based largely upon subjective impression and applying to the years preceding 1847" (1955a, 33), they do suggest that the ethnographic population estimates are likely too low. Baumhoff's (1963) study of ecological determinants of population, showing that the "actual populations" of some groups were well below the numbers predicted on the basis of carrying capacity, also would seem to support higher estimates. The Central and Southern Sierra Miwok, for example, had predicted versus "actual" populations of 8,547 versus 4,410 and 8,503 versus 5,766, respectively (Baumhoff 1963). Moreover, the density of late prehistoric sites in many Sierran localities would suggest a level of occupational intensity greater than implied by ethnographic testimony. All things considered, 90,000–100,000 seems a reasonable approximation of the number of Native Americans living in the Sierra Nevada during the early 1800s. Ecological implications of this population level are discussed later in this chapter.

Native Americans Today

Although today their ancestral lands are occupied mostly by other peoples, each Native American polity in the Sierra Nevada has maintained a distinct ethnic identity. Their contemporary needs, goals, and worldviews have stemmed from a difficult past, including 200 years of Indian resistance to Euro-American appropriation of their land and natural resources (Cook 1976a; Heizer 1974; Hurtado 1988; Phillips 1993; Rawls 1984). Many of the native groups regulate their business and conduct financial affairs through formal tribal councils. Some tribes own and operate their own museums. Intra- and inter-tribal gatherings occur up and down the Sierra Nevada annually and are known variously as acorn festivals, Indian days, big times, and powwows. The current activities and lore of the Native Americans have emerged from a blending of ancient botanical knowledge and a sustained interest in their cultural heritage. Language is intimately tied with gathering and management knowledge. Most of the languages in the Sierra Nevada are still spoken, but some of the cultural groups have only one or two fluent speakers left (Hinton 1994). Individuals of both sexes and of all ages still gather plants. Uses of plants and animals that had been relinquished have regained importance among some families in recent years. Most of the tribes in the Sierra Nevada have an insignificant land base or none at all; consequently, they are forced to gather mostly on public lands. The loss of habitat—wetlands, overflow channels of streams, black oak–ponderosa pine mixed conifer forest, and so on—for culturally significant plants is extensive. Newly formed organizations such as the California Indian Basketweavers' Association (CIBA) have expressed concerns, on behalf of their members from different tribes, about such habitat loss and other issues facing those involved in traditional uses of the land.

Despite a turbulent history and subsequent acculturation, California Indian elders are still a substantial source of information about present and former traditional plant uses and management practices, and in some cases elders are still practicing plant management adjacent to their homes. Burning for cultural resources occurred "on the sly" on U.S. Forest Service (USFS) lands as late as the 1950s, and some traditional management is still conducted on several reservations and rancherias. Unfortunately, many plant ecologists and resource managers still distrust or discount this anecdotal information. Yet, some of the richest details of former resource-management practices have come from ethnographic interviews conducted this decade (Anderson 1993b). The accuracy of these accounts is verified through cross-referencing with testimony from other families, both within and between tribes. Oral histories are then combined with information from museum studies, ethnographic and ethnohistoric accounts, and the archaeological record to provide the most thorough reconstruction of past human activities on the land. Native American systems of knowledge about the environment have a great deal to teach resource managers. Some basket weavers have been involved in blending western and nonwestern knowledge systems in on-the-ground resource management on USFS lands (Anderson 1992; CIBA 1993; Lorri Planas, Choinumni / Mono, conversation with M. K. Anderson, 1994).

Past Economic Activities

To meet their basic needs, native peoples of the Sierra Nevada practiced such diverse subsistence activities as gathering, hunting, fishing, firewood use, and toolstone quarrying. A variety of greens, fruits, bulbs, corms, tubers, and mushrooms was gathered by each community. Staple foods included acorns from oaks (Quercus douglasii, Q. chrysolepis, Q. kelloggii, Q. wislizenii, Q. garryana, Q. vaccinifolia, Q. berberidifolia) and a number of small, hard seeds from native grasses and broad-leaved herbaceous plants. Additionally, native peoples procured deer, fish, small game, insects, and other animals (Barrett and Gifford 1933; Curtis 1924; DeQuille 1963; Merriam 1955; Powers 1976). This diversity of food resources was obtained by following an annual cycle of population movements that coincided with seasonal availability of specific resources; often this involved warm-season abandonment of villages in the foothills as populations dispersed to small, temporary camps at higher elevations (Barrett and Gifford 1933; Kroeber 1925). In addition to acquiring plants and animals for food, Native Americans gathered large quantities of plant material for firewood, basketry, cordage, and construction purposes. Native American relationships to the land were highly interactive. Areas were manipulated annually, biennially, triennially, or quadrennially to augment wild plant populations and create shifting mosaics of different vegetation types. Both small patches and extensive areas of vegetation were burned, and individual plants were pruned, dug, shaken, knocked, or weeded (Clara Charlie, Chukchansi-Choinimni Yokuts, conversation with M. K. Anderson, 1990; Bill Franklin, Sierra Miwok, conversation with M. K. Anderson, 1990; Grace Tex, North Fork Mono, conversation with M. K. Anderson, 1991).

Past Land-Management Practices and Ecological Consequences

Until recently, vegetation types in the Sierra Nevada were viewed as "natural," and their productivity was maintained through natural disturbance in the complete absence of human influence (Nichols 1989; Parsons et al. 1986). It is now recognized that many ecosystems in the Sierra Nevada evolved through significant human intervention (Blackburn and Anderson 1993; Lewis 1993; Wagner and Kay 1993). The ability of Native Americans to meet their economic needs was sustained not only through hunting, fishing, and gathering but also through a variety of horticultural techniques including burning, irrigating, pruning, selective harvesting, sowing, and weeding. These horticultural practices were exercised most commonly in five Sierran vegetation types: foothill woodland, chaparral, mixed conifer forest, riparian corridor, and meadow. Fire was the most important management tool, employed by the Native Americans to clear brush, maintain grasslands and meadows, improve browse for deer, enhance production of basketry and cordage materials, modify understory species composition in forests, and reduce fuel accumulation that might otherwise sustain intense fires. Ecological effects of horticultural techniques varied in time and space, depending upon the cultural objective and plant-community type. Some of the horticultural techniques used by native peoples of the Sierra Nevada and a general definition for wild-plant management are summarized as follows.

Wild-plant management is the human manipulation of native plants, plant populations, and habitats, in accordance with ecological principles and concepts, that effects a change (either beneficial or negative) in plant abundance, diversity, growth, longevity, yield, and quality to meet cultural needs (Anderson 1993a). Management techniques include:

Burning: applying fire to particular vegetation areas under specified environmental conditions and descriptors such as seasonality, fire-return interval, and dimensions to achieve select cultural purposes.

Irrigating: supplying select land areas with water by means of diversion and artificial channels.

Pruning: removing dead and living parts from native plants to enhance growth, form, or fruit and seed production.

Selective harvesting: harvesting in a discriminate, repetitive manner that leads to intended or unintended selection of traits, which in turn leads to evolutionary modifications such as enlargement of the favored plant part, reduction of the potential for reproduction by seed, or color changes in the fruit or seed.

Sowing: broadcasting seed collected from native plants onto an area, usually recently burned ground.

Tilling: removing earth in the harvest of underground perennial plant organs (e.g., roots, rhizomes, corms, bulbs), frequently followed by the subsequent dividing of these organs and leaving of individual fragments in the soil.

Transplanting: digging up a plant or a portion of a plant and moving it to another place.

Weeding: removing unwanted plant species near favored plant species.

There are three broad realms in which Native Americans acted as agents of environmental change:

1. Dispersal agents. Native Americans were intentional and sometimes inadvertent agents of plant dispersal that has rearranged the distribution of some species and created unusual plant distributions and polymorphisms.
2. Agents of habitat modification. Native Americans expanded and maintained suitable habitat in both time and space for desired species without necessarily altering character traits.
3. Agents of genetic modification. Native Americans modified the gene pools and genetic structures of plants through selective harvesting and transplanting. Over hundreds to thousands of years, specific genotypes of many intensively used plant species were selected by Native Americans and therefore probably still exhibit character traits that are adapted to small-scale human disturbance regimes.

The potential linkage between a culture's horticultural practices, uses of particular plant species, and selection pressures exerted on those species has not been sufficiently studied. For example, as a demonstration of combined dispersal and selection, the high variability in blue camas (Camassia quamash) in the Sierra Nevada is probably due to the trading and selective harvesting practices of different tribes (Susan D'Alcamo, conversation with M. K. Anderson, 1993). One possible study would be to compare the morphological variation in populations of a native species gathered in several different tribal territories with the differences in local harvesting and management regimes.

Past Land-Ownership Patterns

Native American societies recognized territorial boundaries and community ownership of land coupled with individual responsibility for resource conservation and use (Kroeber 1925, 1962). Increasing evidence shows that use and improvement of areas through cultivation gave a family or community exclusive use rights to that area. Thus, within each tribal territory there were numerous traditional collection sites for basketry material, acorns, clover, mushrooms, cordage fibers, and so on (Curtis 1924; Gayton 1948; Wilson 1972; Norma Turner, Mono, conversation with M. K. Anderson, 1992). Euro-American law and practice, imposed upon the Sierra Nevada during the mid-nineteenth century and subsequently, enshrined private ownership rights even at the expense of community interests. These sharp cultural differences are reflected in the land-use practices of pre- and post-contact populations.

Land-Use Ethic

Although Native American economic and management practices in the Sierra Nevada were diverse, they were nonetheless unified by a fundamental land-use ethic: to interact with nature respectfully and in ways allowing all life forms to coexist. This ethic transcended cultural and political boundaries.

It comprised spiritual, philosophical, and economic dimensions that encouraged sustained relationships between human societies and Sierran environments over spans of centuries or millennia. In Native American cosmologies, humans are viewed as part of the natural system; thus, all life forms are related to humans and must be treated with respect. Legends, ceremonies, songs, dances, and arts were and continue to be integrated parts of the spiritual systems, instructing the people in right and wrong behavior and the position and obligations of each person within the group (Swezey 1975). Land-use and land-management activities were guided by complex cultural rules, sophisticated knowledge of reproductive biology, and awareness of community ecology. Aldo Leopold's land ethic is most akin to native philosophy in that he advocated that humans should avoid both the dangers of overexploitation and the inactivity of preservation (Callicott 1990). One of the most provocative ideas found in Native American views is that human intervention in nature does not necessarily create disharmony. When Native American elders today are asked what has changed in the Sierra Nevada, they are apt to respond by saying simply, "No one is gathering or tending areas anymore." The idea that human use ensures an abundance and diversity of plant and animal life appears to have been an ancient one in the minds of native people, and there is very likely an ecological as well as a spiritual basis for this belief (Blackburn and Anderson 1993).

EVIDENCE FOR WIDESPREAD MODIFICATION OF SIERRAN LANDSCAPES: SPECIFIC QUESTIONS

Were the Technologies of Native Americans in the Sierra Nevada Capable of Creating Widespread Ecological Change?

Yes. Although most of the prehistoric tools (the digging stick, knocking stick, obsidian knife, seed beater, etc.) used in the Sierra Nevada appear simple and unable to affect vast areas, the fire-making kit allowed people to alter landscapes. Burning was probably the most widely employed, efficient, and significant vegetation-management tool used in the Sierra Nevada (Anderson 1994; Lewis 1993; Reynolds 1959). Knowledge and use of the slow match and torch recorded for most tribes gave native peoples the technological capability to burn either small patches or extensive tracts of vegetation in a systematic fashion. Frequent burning promoted a herbaceous understory vegetation within woodlands and coniferous forests. This continuous and sufficient fuel bed facilitated the burning of land of large areal extent. Felling trees with fire to promote type conversions was a capability of most tribes (Driver 1937; Driver and Massey 1957). Extensive trade networks in the Sierra Nevada promoted the exchange of seeds and other plant parts that could be propagated in new areas. For example, seeds were exchanged between families of Yokuts descent (Gayton 1948). In recent ethnographic interviews, Ruby Cordero (Chukchansi Yokuts) and Hector Franco (Wukchumni Yokuts) have described burning to promote seed crops. Additionally, after being burned, areas were sometimes sown with seed (Hudson 1901; Steward 1938).

Were Native American Settlement and Land-Use Patterns Repetitive and of Adequate Duration to Cause Permanent Effects on the Vegetation?

Yes. Indians have occupied the Sierra Nevada for at least 9,000–10,000 years (Moratto 1984; Moratto et al. 1988). It has been widely assumed until recently that Native Americans in the Sierra Nevada were "hunter-gatherers" who did not practice agriculture and whose environmental impacts were negligible. There is increasing archaeological, paleoecological, ethnographic, and ethnohistoric evidence, however, that human manipulations were regular, constant, and long term, causing cumulative and permanent effects in plant associations, species composition, and in the gene pools and genetic structures of species in a multitude of Sierra Nevada vegetation types (Anderson and Carpenter 1991; Blackburn and Anderson 1993; Anderson 1993a; Kilgore and Taylor 1979). This is not to say that particular land-use and resource-management activities persisted unchanged throughout the Holocene. Indeed, the archaeological record shows that population densities, land-use intensity, and specific economic practices did vary diachronically. Periods of notably intense cultural activity (e.g., ca. 7500–6000 B.C., 1000 B.C.–A.D. 700, A.D. 1300–1800) were separated by times of diminished populations and concomitantly reduced land use. During each interval, prevailing economic practices were applied over a span of centuries. The most recent period of intensive land use endured for some five hundred years before Euro-Americans entered the Sierra Nevada. This interval was long enough that Native American human activities caused substantial environmental effects.

Special areas were designated for basketry materials, bulb gathering, seed collecting, cordage-fiber harvesting, or greens picking and were shaped by continual long-term use and management (Aginsky 1943; Latta 1977; Voegelin 1938). Technologies such as basketry and cordage are extremely ancient fiber arts in North America; basketry fragments radiocarbon-dated to more than 10,000 years B.P. have been found in western North America (Adovasio 1974). These fragments demonstrate qualities that show that they were manufactured with the same techniques as those used for historic baskets. Presumably, fire was employed to stimulate the production of long shrub shoots wherever the basketry craft diffused in California. Additionally, management of gathering sites was a way of visually marking one's relationship with the area and was a signal for gaining land-use rights. Place names, ethnographic work with contemporary elders in different tribes, and the ethnohistoric and ethnographic literature all substantiate the fact that resources were gathered from long-term collection sites inherited through relatives (Gladys McKinney, Dunlap Mono, conversation with M. K. Anderson, 1992; Norma Turner, Mono, Dumna Yokuts, conversation with M. K. Anderson, 1991).

Was the Protohistoric Human Population in the Sierra of a Magnitude Sufficient to Cause Widespread Ecological Impacts?

Probably. The carrying capacity of Sierran environments for human populations varied significantly in space and time. By 1000 B.C. the west side of the Sierra Nevada was widely and intensively inhabited (Moratto 1984). The Native American population of the Sierra Nevada in A.D. 1800 was probably on the order of 90,000–100,000 (supra). There is no known archaeological evidence for larger numbers at any earlier time, although populations during the 1000 B.C. to A.D. 500 interval might have been comparable to those of late prehistoric times, ca. A.D. 1300–1800 (Moratto et al. 1988).

One measure of impact potential is population density. Kroeber (1939) calculated densities per 100 km^2 (39 mi^2) of 0–5 for the Northern Paiute; 10–25 for the Washoe, Owens Valley Paiute, and Western Mono; 25–45 for the Maidu, Konkow, and Nisenan together; 45–70 for the Sierra Miwok; and 70-plus for the Foothill Yokuts. Other estimates of population densities for Sierran tribes tend to be similar or higher (cf. Baumhoff 1963; Cook 1955a, 1976a, 1976b). Populations were not distributed evenly within any territory, but rather were concentrated near major streams in the upper Sonoran and lower Transition zones. Because of seasonal movements, a single community could affect environments in several localities at different elevations during the course of its annual cycle of dispersion and aggregation.

If one assumes a pre-contact Sierran population of about 100,000 distributed among settlements averaging, say, thirty-five residents each (five houses of seven residents each), then at any given time there would have been roughly 2,860 settlements, each of which would have required firewood, fish and game, vegetal foods, craft supplies, and construction materials for dwellings and sweat houses, ramadas, grinding booths, granaries, and, in principal villages, ceremonial lodges. Allowing for seasonal relocations and special-use camps, the number of sites occupied per year easily could have been 5,000–10,000. The magnitude of impact would have reflected not only the direct results of occupation per se (involving perhaps a few hectares per settlement) but also resource extraction, effects of predation, and intentional burning within a catchment of perhaps 5–10 km^2 (2–4 mi^2).

Not enough is known about the resource requirements and extent of land managed to meet those demands of each tribe's settlements. Quantitative models based upon detailed archaeological studies and analyses of museum specimens gathered from fire-managed areas, as well as careful experimentation and replication, need to be developed to better understand the sustained resource needs of a typical, pre-contact Sierra Nevada community (Blackburn and Anderson 1993). One thing is clear: modern population levels and trends in the Sierra Nevada are unprecedented and already exceed those of pre-contact Native Americans by more than an order of magnitude.

Which Land-Use Activities Required the Highest Quantity of Plant Material from Managed Environments?

Basketry, cordage, firewood, and foods. These cultural use categories required gathering on a frequent, repetitive basis and demanded the collection of large amounts of plant materials from managed environments. For example, the basket-weaving industry required a large-scale effort to manage, harvest, size, cure, and weave plant materials into baskets for each village. This industry was at the very heart of Native American material culture in the Sierra Nevada. Specialized baskets were manufactured variously to serve as seed beaters, winnowing devices, burden packs, storage containers, cooking vessels for stone-boiling of mush, parching trays, bowls and cups, cradleboards, and fish traps, and for myriad other uses. Practicing the art of basketry demanded a steady, large supply of uniform plant materials for weaving. Hundreds of thousands of young shoots from different plant species were needed annually. These amounts were sufficiently large as to make opportunistic gathering (wherever one might find the right material) prohibitive. Thus, collecting basketry material was not happenstance, but was, rather, a sizable collective enterprise (table 9.1).

Great efficiency was needed to gather enough materials yearly to comply with the strict standards for the manufacture of many cultural items. Most of the basketry materials could not be used right away, but required a storage period to season them. This period varied from one to four years depending upon the plant species (Bates and Lee 1990; Margaret Mathewson, conversation with M. K. Anderson, 1992). Women had to plan ahead, gathering that year's new growth for a basket they might make two or three years later. To rely on natural fires from lightning to induce production of large numbers of desirable shoots would be risky, because lightning could strike in the wrong plant-community type, not strike in a location with suitable kinds of plant species, or hit too far away. Setting fires in the area where the plants grew was far more efficient. These facts support a burning regime that was very frequent, to keep shrubs at a young growth stage in order to obtain a continuous supply of a tremendous quantity of usable shoots for the making of many kinds of baskets.

Firewood, too, was required in large quantities. Domestic fires were used to singe game, braise meat, preheat earth ovens, heat stones for boiling acorn and other foods, raise the

TABLE 9.1

Comparison of numbers of useful shoots from unmanaged versus managed shrubs used for Western Mono basketry[a] (adapted from Anderson 1993b).

Basket Type	Plant Species Used	Shoots per Basket	Unmanaged Plants per Basket	Managed Plants per Basket
Burden	*Ceanothus cuneatus*	2	10 shrubs	1 shrub
	Rhus trilobata	1,200 (1.2 m each)	400 patches	12 patches
	Cercis occidentalis	25 (1.8 m each)	50 shrubs	1 shrub
Full-sized	*Rhus trilobata*	675	102 patches	6 patches
cradleboard	*Cercis occidentalis*	75 (1.8 m each)	150 shrubs	6 shrubs
	Ceanothus cuneatus	13	65 shrubs	1 shrub
Twined seed beater	*Ceanothus cuneatus*	2 (for rim)	10 shrubs	1 shrub
	Ceanothus cuneatus	188 (for warp and weft)	376 shrubs	15 shrubs
Seed gathering	*Ceanothus cuneatus*	2 (for rim)	10 shrubs	1 shrub
	Ceanothus cuneatus	376 (for warp and weft)	752 shrubs	31 shrubs
	Cercis occidentalis	50	100 shrubs	4 shrubs
Twined sifter	*Rhus trilobata*	1,000 (1.1 m each)	333 patches	10 patches
	Cercis occidentalis	25 (1.8 m each)	50 shrubs	2 shrubs

[a]Based on discussions with Norma Turner (Western Mono weaver). Management methods are pruning and burning.

Conversions:

Unmanaged *Cercis occidentalis*	Managed *Cercis occidentalis*
1 1.8 m shoot/shrub	25 1.8 m shoots/shrub
3 0.9 m shoots/shrub	25 0.9 m shoots/shrub
Unmanaged *Rhus trilobata*	Managed *Rhus trilobata*
10 short shoots/patch	100 short shoots/patch
3 long shoots/patch	100 long shoots/patch
Unmanaged *Ceanothus cuneatus*	Managed *Ceanothus cuneatus*
1 rim shoot/5 shrubs	2 larger-diameter shoots/shrub (for rim)
2 smaller shoots/shrub	10–15 smaller-diameter shoots/shrub (for warp and weft)

temperature in sweat houses, provide illumination after dark, and warm houses during cold weather. Fires were also used to fell and cut trees for house posts and rafters, to char post butts (as a wood preservative), and, among the Yokuts, Mono, and Paiute, to fire pottery (Gayton 1929; Liljeblad and Fowler 1986). In addition, many Sierran groups cremated their dead (Gifford 1955; Gould 1963; Kroeber 1925). Thus, firewood use was substantial. Assuming a pre-contact average of 2,860 settlements with five houses each (supra), and allowing, as a guess, 10 kg (22 lb) of daily firewood use per household, Native Americans would have burned some 143,000 kg (314,000 lb) of fuel each day. Annually, this would have amounted to 52,195 metric tons (51,165 tons avoirdupois). Further assuming that 5,000–10,000 sites were occupied each year, the average fuel consumption per settlement would have been roughly 5.8–11.5 metric tons (5.2–10.4 English tons). Some of the larger villages, with 300–500 members, might well have collected 250 metric tons or more of firewood annually. Such quantities not only would have reduced the fuels available to sustain natural fires, but also might have depleted supplies of firewood in some places sufficiently to require people to relocate.

Which Land-Use Activities Had the Greatest Impact on Sierran Plant Communities?

The single most important reason mentioned by Native American elders when asked why their ancestors burned in the Sierra Nevada was to keep the underbrush down to prevent a large, devastating fire (Clara Charlie, Chukchansis-Choinumni, conversation with M. K. Anderson, 1991; Bill Franklin, Sierra Miwok, conversation with M. K. Anderson, 1990; Ron Goode, North Fork Mono, conversation with M. K. Anderson, 1991). Tragically and ironically, many of the elders interviewed had lost their homes to fire—including precious baskets, mortars and pestles (cracked from the fire intensities), and other valuable cultural items—because of fuel accumulations on adjacent public lands due to fire-suppression policies. Accounts of past burning to keep the brush down are rich and varied:

> My great aunt and mother talked about how the land was burned. If there was brush, they'd burn in the ponderosa pine and sugar pine areas. I remember there wasn't the tall brush that there is now. It's hopeless. They've let it go for so long. So when it does burn it goes and goes and kills the big trees. When they'd set the fires, it wouldn't hurt the trees.
>
> They'd burn from the bottom of the slope. They would burn in the fall after rains. They would touch off any of the brush. It would burn some of the new needles off but it wouldn't burn way down through the duff like it does with the controlled burning today. They wouldn't burn the whole area, but anywhere it needed it. (Nellie

Williams, North Fork Mono, conversation with M. K. Anderson, 1991).

> Maria Lebrado used to burn the hills on her property. The white man sure ruined this country. It's turned back to wilderness. In the old days there used to be lots more game—deer, quail, gray squirrels, rabbits. They burned to keep down the brush. The fires wouldn't get away from you. It wouldn't take all the timber like it would now. Burns were started in October, November, or December, not in January at the bottom of the slope. They burned every year. The fires wouldn't get up in the trees. There wasn't enough vegetation to get up in the trees. The plants were widely spaced. It wouldn't scorch except a few trees. They never talked about burning in the giant sequoias. They used to burn the high country in Yosemite and Crane Flat around 6,000 ft elevation. (Jim Rust, Southern Sierra Miwok, conversation with M. K. Anderson, 1989).

Clearly "burning to clear out the brush" was extremely important among native cultures. When analyzed, this purpose was perhaps the most significant reason of all for burning. Indians of the Sierra Nevada were very much aware of the double-edged sword of fire—that it could be beneficial or harmful to plant resources. For example, Native Americans actively managed vegetation patterns with fire to prevent intense fires that would promote tree scorching, which would harm valuable plant resources such as black oaks (Anderson 1993b).

A severe fire in a tribal territory would mean not only immediate loss of property, resources, and perhaps lives, but also disaster for the long-term well-being of a community. A catastrophic forest fire of the kind witnessed during the last several years, for example, could destroy hundreds or thousands of hectares of important game habitat and plant food resources. If many of the foothill pines, black oaks, sugar pines, and blue oaks were destroyed at important gathering sites, a substantial portion of the food supply would be lost. "Burning to keep the brush down" provided the environmental context within which more localized burning could then be done for specific cultural purposes. Frequent burning was the insurance policy against annihilation of important gathering and village sites.

That there were large areas of impenetrable growth in the Sierra Nevada in the middle to late 1800s is undeniable (Dudley 1896; Perlot 1985). Had the Indian burning patterns already been largely disrupted even before the arrival of the cattlemen, gold miners, and earliest settlers? Was the native population drastically reduced (because of exotic diseases), and was the brush therefore more widespread than during pre-contact times? Some scientists have argued that the population of California's Indians was not large enough and that they were not technologically capable of setting huge portions of California on fire (Burcham 1959; Clar 1959). However, if each pre-contact Indian household had burned only 10 hectares (25 acres) per year, about 143,000 ha (353,000 acres) of the Sierran landscape could have been altered annually, and many times more than this during the multiyear fire intervals. Accurate estimates of the areal extent of indigenous burning will require far more intensive studies than have yet been undertaken. Detailed studies of late prehistoric and early historic aboriginal populations in the Sierra Nevada are particularly needed.

How Were Selected Plant Species Affected by Protoagricultural Intervention?

Native Americans in the Sierra Nevada in many cases selected plant species that thrive under repeated disturbance. Cultural groups used a wide variety of plant species for many different products, but they relied heavily on a small subset of the total Sierran flora to meet their major needs. The cultural use categories that required continuous gathering of large amounts of plant parts are building construction, firewood, basketry, cordage, and foods. The understanding, exploitation, and modification of vegetative or asexual reproduction of plant species were extremely important to Indian subsistence economies. Vegetative reproductive structures have evolved with environmental disturbance in the form of flooding, fire, and small mammal and large mammal (grizzly bear, elk) activity, and human perturbations, therefore, frequently mimicked such natural disturbances. Multiplication and selection were often from clones. According to Sauer (1952), an individual plant with strong vegetative reproductive mechanisms might be divided and multiplied indefinitely. Vegetative reproduction exploited by Native Americans is of six major forms: offsets, tubers, stolons, perennial creeping root stocks, adventitious and epicormic shoots, and rhizomes. The new plant is an identical reconstitution of the parent rather than variant progeny (Sauer 1952). Native Americans gathered vegetative reproductive parts and progeny and maintained the parent plant in situ. Other gathering strategies that ensured long-term, repetitive collection in the same areas were gathering of sexual reproductive parts with maintenance of parent plant in situ and gathering of sexual reproductive parts with some seed replacement.

Indian Disturbance Regimes: Some Examples

Basketry-Production Systems. The adaptive significance of vegetative reproduction in shrubs has long been a major topic of inquiry by ecologists and evolutionary biologists (Keeley 1986; Naveh 1975; Wells 1969). Within the native flora of the Sierra Nevada are numerous species that display adventitious and epicormic sprouting capability (Kauffman and Martin 1990). All native groups in the Sierra Nevada burned and/or pruned areas in mixed conifer forests, riparian areas, oak woodlands, and chaparral to promote the growth of adventitious shoots and epicormic branches of native shrubs such as sourberry (Rhus trilobata), willows (Salix spp.), redbud (Cercis occidentalis), and hazelnut (Corylus cornuta var. californica) (Fowler 1986; Gamble et al. 1979; McMillin 1963; Potts 1977; Clara Charlie, Chukchansi-Choinumni Yokuts, conversation with M. K. Anderson, 1990; Ruby Cordero, Chukchansi Yokuts-Sierra Miwok, conversation with M. K. Anderson, 1991; Amy Rhoan, Paiute, conversation with M. K. Anderson, 1990). All these species are believed to have displayed such growth behavior long before human management. In such cases, human management merely expanded the suitable ecological conditions that favored such growth. Most fires were set in the fall, after one or two rains, and they were set frequently (one- to several-year intervals). These fires were ignited from the bottom of the slope and were of an unknown areal extent, but probably the cumulative acreage was substantial given the density and dispersion of humans in the Sierra and the fact that large amounts of young growth were required for each village (Anderson 1993b).

Basketry was a highly developed technology in the Sierra Nevada, and the tradition is still maintained today. Historically, the use of baskets was so central to daily living that it represented 50% of the plant material culture (excluding construction materials) of the sixty or so tribes in the state (Anderson 1993a). One medium-sized cooking basket, for example, could take several thousand redbud first-year shoots to complete. The numbers of young shoots occurring "naturally" on wild shrubs are very few, justifying the need for frequent management. Native Americans set fires in ways that perpetuated native shrub species having protected, subterranean plant organs, which allowed for subsequent, in situ development. After the fires were set, hundreds of thousands of first-year shoots of various native shrubs were harvested in the following fall, winter, or early spring. Young growth was highly valued by weavers because it displayed such physiological and morphological features as anthocyanins, uniform cell density, flexibility, straightness, absence of lateral branching, and long length, which facilitated optimal construction of baskets. Additionally, young growth lacked insect or pathogen activity that would weaken basketry material (Anderson 1991).

Food-Production Systems. Leaves for greens, fruits, mushrooms, and bulbs were the edible plant parts that were managed for with fire in late summer to late fall by tribes throughout the Sierra Nevada to maintain their quality and quantity.

Fruits: Burning of chokecherries, manzanita berries, strawberries, and elderberries has been recorded among the Maidu, Foothill Yokuts, Western Mono, and Miwok tribes to increase fruit production, thin dense shrub canopies, reduce insect activity by eliminating old wood (Jewell 1971, as quoted in Roper Wickstrom 1987; Lydia Beecher, Mono, conversation with M. K. Anderson, 1991; Hector Franco, Wukchumni Yokuts, conversation with M. K. Anderson, 1991; Avis Punkin, North Fork Mono-Miwok, conversation with M. K. Anderson, 1991).

Greens: Burning of herbage for better wild crops was recorded among the Chukchansi Yokuts; Western Mono; Southern, Central, and Northern Miwok (Aginsky 1943) to promote palatable growth, increase seed production, extend the gathering tract, and keep greens collections areas free and open. For example, clover (Trifolium spp.) patches were burned in Wukchumni Yokuts territory in October and November and in North Fork Mono territory (Rosalie Bethel, North Fork Mono, conversation with M. K. Anderson, 1991; Hector Franco, Wukchumni Yokuts, conversation with M. K. Anderson, 1992).

Mushrooms: Mushroom patches were burned by the Western Mono to improve quality and promote abundance. Species include Morchella elata, Peziza spp., Amanita spp., and Ramaria spp. (Goode 1992; Hazel Hutchins, Mono, conversation with M. K. Anderson, 1992; Nellie Williams, North Fork Mono, conversation with M.K. Anderson, 1991; Dave Bowman and Ed Bowman, Wobonuch Mono, conversation with M. K. Anderson, 1991).

Bulbs, corms, and tubers: Areas were burned by the Southern Sierra Miwok, Western Mono, and Northern Hill Yokuts to reduce competitive shrubs and grasses, recycle plant nutrients, heighten the size and quantity of underground swollen stems, and keep areas open to maintain these crops. Species included Perideridia spp., Sanicula spp., Brodiaea spp., and Allium spp. (Baxley 1865; Lydia Beecher, Mono, conversation with M. K. Anderson, 1991; Ruby Cordero, Chukchansi Yokuts-Miwok, conversation with M. K. Anderson, 1991; Ella McSwain, North Fork Mono, conversation with M. K. Anderson, 1991).

Seeds: Seed-collection sites were burned by the Western Mono, Paiute, Maidu, Nisenan, Northern Hill Yokuts, and Sierra Miwok to eliminate insects and diseases, recycle nutrients, keep open areas within forests and dry montane meadows, eliminate weed competition, augment seed production, and eliminate detritus of perennial grasses. Species included Astragalus bolanderi, Lathyrus sulphureus, Pickeringia montana, Wyethia spp., Salvia columbariae, and Calandrinia ciliata (Driver and Massey 1957; Gayton 1948; Hudson 1901; Kroeber 1925; Anonymous elder, North Fork Mono, conversation with M. K. Anderson, 1991; Hector Franco, Wukchumni Yokuts, conversation with M. K. Anderson, 1991).

Cordage-Production Systems. Cordage can be defined as "the twisting together of separate fiber strands into a single, long twined string or rope" (Mathewson 1985). Making of string or cordage is perhaps the oldest fiber art in America (Adovasio 1974). Native peoples probably brought cordage technology with them when they first entered California. The most important cordage-fiber plants used by native peoples in the Sierra Nevada were Indian hemp (Apocynum spp.) and milkweed (Asclepias spp.). These two genera contain herbaceous species with stems that are composed of excellent "bast" fibers. These fibers were collected, extracted, and manufactured into many items, including nets for fishing, deer nets, rabbit nets, netting bags, tump lines, slings, flicker feather head bands, hair nets, feather capes, feather skirts, belts, cord belts for women's aprons, and bow strings.

Herbaceous plants that contained desirable fiber were gathered primarily in the late fall or winter when the stalks had died back (Barrett and Gifford 1933). Cordage plants were periodically burned in the fall to decrease accumulated dead material, provide increased access for harvesting, allow greater sunlight to the new growth, and recycle nutrients to the soil. Plants were reputed to grow straighter and taller when burned (Peri et al. 1982; Rosalie Bethel, Mono, conversation with M. K. Anderson, 1991; Hector Franco, Wukchumni Yokuts, conversation with M. K. Anderson, 1991). Large quantities of Indian hemp and milkweed were harvested to make different cultural items (table 9.2), suggesting that the cumulative acreage burned to maintain productive collection sites was probably substantial. For example, a 12 m (40 ft) deer net made by the Sierra Miwok would require 2,134 m (7,000 ft) of string, or 35,000 plant stalks (Craig Bates, conversation with M. K. Anderson, 1992).

Native American Resource Management at Different Levels of Biological Organization

Horticultural techniques were applied at different levels of biological organization. Thus, the ecological consequences of these techniques would register at the following scales:

Organism Level. Individual plants were manipulated through spot burning and pruning to enhance production of a desired plant part. For example, single shrubs of buttonbush (Cephalanthus occidentalis) and willow (Salix sp.) were pruned for arrow-shaft material, elderberry (Sambucus mexicana) shrubs were coppiced for musical instruments, and brush was piled on individual shrubs of maple, redbud, and oak and set on fire to induce long shoots for basketry and looped stirring sticks (Anderson 1993b).

Population Level. Stands of bunchgrass (e.g., Muhlenbergia rigens) for basketry, herbaceous plants for cordage (e.g., Apocynum cannabinum), edible plants for greens (e.g., Trifolium spp.), seeds (e.g., Madia spp., Wyethia spp.), and corms, tubers, and bulbs (e.g., Perideridia and Sanicula spp.) were set afire to enhance quantity and quality, reduce plant competition, and keep surrounding vegetation from encroaching (Anderson 1993b). Populations of blue dicks (Dichelostemma capitatum) and yellow nut grass (Cyperus esculentus) were irrigated in Owens Valley by the Paiute (Lawton et al. 1976).

Plant-Community Level. Vegetation dominated by foothill woodland or coniferous forests was managed for maximum complexity of the vertical structure to encourage a variety of plant species in the understory. Disturbance, in the form of burning and digging, was frequent and of an intensity and scale to prevent monopolization of resources by one or a few species.

Landscape Level. Native Americans introduced burning to maximize plant-community diversity. Particularly important was promoting pioneer stage and fire subclimax plant communities. "Burning to keep the brush down" was a maxim adhered to by all Sierran peoples. Burning expanded special plant-community subtypes such as black oak–ponderosa pine, prolonged the life of dry meadows, and cleared out reed-choked marshlands (McCarthy 1993; Hector Franco, Wukchumni Yokuts, conversation with M. K. Anderson, 1992). Fire mosaics promoted an abundance of water in numerous springs and creeks (Duncan 1964; James Rust, Southern Si-

TABLE 9.2

Quantities of cordage material (*Apocynum* and *Asclepias* spp.) gathered for various cultural items by Native Americans of the Sierra Nevada (adapted from Lindstrom 1992; Anderson 1993a).

Tribe	Cultural Item	Use	Dimensions	Total Cordage Length	Stalks Gathered (Number)
Washoe and Northern Paiute	Gill net	Fishing	1.6 mm 2-ply 30 m x 1.4 m x 38 mm mesh (1/16" 2-ply 100' x 4.5' x 1.5" mesh)	3,665 m (12,022 ft)	60,110
Washoe and Northern Paiute	Bag net	Fishing	1.6 mm 2-ply 0.75 m x 0.75 m x 0.75 m x 25 mm mesh (1/16" 2-ply 2.5' x 2.5' x 2.5' x 1" mesh)	270 m (885 ft)	4,425
Washoe and Northern Paiute	A-frame dip/lift net	Fishing	1.6 mm 2-ply 2.1 m sq. x 1.2 m (x 4 panels) x 25 mm mesh (1/16" 2-ply 7' sq. x 4' [x4 panels] x 1" mesh)	2,405 m (7,890 ft)	39,450
Sierra Miwok	Feather cape	Ceremony	1.6 mm 2-ply 44.5 mm mesh (1/16" 2-ply 1.75" mesh)	30 m (100 ft)	500
Sierra Miwok	Deer net	Hunting	3.2 mm 2-ply 12.2 m x 1.8 m x 102 mm mesh (1/8" 2-ply 40' x 6' x 4" mesh)	2,134 m (7,000 ft)	35,000

erra Miwok, conversation with M. K. Anderson, 1989). Burning at higher elevations was for the expressed purpose of removing shrub and duff layers, promoting a more tightly assembled snowpack. This dense snowpack melted off more slowly, reducing flooding and causing ephemeral creeks and streams to run longer in the summer (Jewell 1971). Strategies for maintaining ecosystem integrity included

- hand clearing and burning detritus that might alter moisture and soil conditions—which would encourage a new array of plant species to colonize
- hand weeding and burning to maintain ecotones around special plant-community types such as meadows
- not obstructing, but rather maintaining and encouraging recurrent changes in water level and scouring along streams and marshes

Once exotic herbaceous species had begun to spread into the Sierra Nevada, they were readily incorporated into the ethnobotanies of the tribes. For example, wild mustard (Brassica spp.) leaves were consumed by the Maidu, Yokuts, and Tübatulabal (Duncan 1964; Gayton 1948; Latta 1977; Voegelin 1938). Fillaree (Erodium cicutarium) greens were eaten by the Maidu (Duncan 1964). Wild oat (Avena fatua and A. barbata) seeds were prized by the Sierra Miwok, Yokuts, and Tübatulabal (Barrett and Gifford 1933; Gayton 1948; Latta 1977). Brome (Bromus rigidus) seeds were added to the Miwok diet (Barrett and Gifford 1933), and Echinochloa crusgalli and Polypogon seeds were eaten by Tübatulabal (Voegelin 1938). Tribes burned areas to promote the growth and abundance of native plants for edible seeds and greens. After the introduction of exotics, burning probably continued. Because many of these exotic species thrive after periodic burning, indigenous burning perhaps contributed to expansion of the range and distribution of these aliens.

ECOLOGICAL CONSEQUENCES OF REMOVING NATIVE AMERICANS FROM TRADITIONAL ECONOMIC AND LAND-MANAGEMENT ROLES

There is a growing awareness that the decline of biodiversity in the United States may be tied directly to past fire-suppression policies of land-managing agencies (National Research Council 1992). New studies concerned with rare and endangered species in the Sierra Nevada (Boyd 1987; Verner et al. 1992) are concluding that frequent fire is necessary to the health and maintenance of habitat for certain endangered biota. Fire-suppression policies on public lands were based on a perception of fire as a destructive force without an understanding of the dynamics of fire and its ecological role; hence, those policies constituted a real threat to the very resources they were intended to protect. Fire is now a widely accepted management tool in conservation biology (National Research Council 1992). But prescribed-burning programs on public lands adjacent to urban areas are hampered by increasing fire risk, threatening human safety and valuable property. Additionally, when prescribed-burning programs are implemented, they are usually done with little or no understanding of the former role of Native Americans in setting fires and creating other kinds of human disturbances. In this light, some scientists now recognize that wildfires in the Sierra Nevada often are more severe and larger than were the wildland fires in aboriginal times and that, therefore, the wildland ecosystems are also at risk (Martin and Sapsis 1992).

Most of the plants useful to Sierran tribes are highly shade intolerant and qualify as early- to mid-successional species. That these early stages were most useful for indigenous needs has been pointed out by previous studies (Lewis 1993; Reynolds 1959). Gaps or grassy openings were created, maintained, or enlarged within diverse plant communities, resulting in many "patches" of plants in varying successional states. Human disturbance at gathering sites was a regular element of the system. For example, fire was used to maintain patches of deergrass (Muhlenbergia rigens) for basketry within mixed conifer forests and chaparral areas; patches of edible native grasses and forbs (Fragaria californica, Madia spp., Salvia columbariae) within oak woodlands and mixed coniferous forests; and patches of edible bulbs, corms, and tubers (Perideridia spp., Sanicula spp.) in the dry montane meadows, open understories of coniferous forests, and openings in chaparral (Anderson 1993b). The result was that plant diversity was maximized.

The heterogeneity of ecological communities was expanded through indigenous manipulations. Mixed conifer forests and oak woodlands were often managed for maximum complexity of the vertical structure to encourage a variety of plant species in the understory. Thus, woodlands and forests often exhibited widely spaced trees, giving better light interception and ultimately leading to an increase in species diversity in an area (Huston 1994). Frequent burning recycled nutrients, destroyed insects and diseases, and promoted a lush understory vegetation that provided an important food supply for Sierran tribes. A variety of understory plant species supported an abundant and diverse insect and small-mammal population, providing a valuable food source to the California spotted owl (Verner et al. 1992).

Old growth in mixed conifer forests in the Sierra Nevada featured large-diameter, healthy individuals, 12–18 m (40–60 ft) apart. The open-growth architecture made these trees more drought tolerant and disease and insect resistant than those of our overstocked forests today. Native grasses, promoted through burning, created a permeable forest soil surface that checked surface erosion. Soil fertility was enhanced by continuously decomposing feeder roots. Downed logs and snags were left intact by light surface fires and supplied nutrients, wildlife habitat, and moisture reservoirs (Martinez 1993). The tree plantations and second-growth forests in many parts of the Sierra Nevada today are structurally and biologically less diverse than natural forests under Native American burning regimes and contain impoverished faunas (cf. Mayer and Laudenslayer 1988; Verner and Boss 1980).

Ecologists hypothesize that plant communities subjected to intermediate levels of disturbance size, frequency, and intensity exhibit high levels of species diversity and high productivity (Connell 1978). The emerging subfield of "patch dynamics" in the discipline of plant ecology recognizes the key role of disturbances such as windstorms, lightning fires, lava flows, and modern human interventions in directing the successional patterns and evolution of plant populations (Mooney and Godron 1983; Pickett and White 1985). It is proposed that the Native American role in creating these "patches" in the landscape was considerable, and in the absence of native burning practices these patches are now undergoing accelerated successional changes.

Indigenous Knowledge and Rare and Endangered Plant Species

Certain plants integral to traditional cultures in the Sierra Nevada are now on rare and endangered or uncommon species lists assembled by the California Native Plant Society. These include such species as Pringle's yampah (Perideridia pringlei), Kaweah brodiaea (Brodiaea insignis), and coyote thistle (Eryngium vaseyi) (Zigmond 1981; Hector Franco, Wukchumni Yokuts, conversation with M. K. Anderson, 1992). The rare and endangered status of plant species is often attributed to habitat fragmentation and habitat loss due to development. Another tack worth investigating is the role that indigenous use and management played in maintaining these plant populations. In the absence of these former human disturbances, plant populations may have declined.

Cultural knowledge of native peoples may be useful in restoring and managing other rare and endangered plants in the Sierra Nevada such as three-bracted onion (Allium tribracteatum) and Small's southern clarkia (Clarkia australis). Although we have no evidence that these species were used by Native Americans in the Sierra Nevada, we know that other species of the same genus were gathered and managed. These techniques may be transferable, across species of the same genus, and are worth investigating (table 9.3). For example, the North Fork Mono formerly burned common Wyethia spp. to maintain seed production (Rosalie Bethel, North Fork Mono, conversation with M. K. Anderson, 1991). Hall's wyethia (Wyethia elata) is uncommon, and El Dorado County mule ear (Wyethia reticulata) is endangered (Smith and Berg 1988). Both species occur in the Sierra Nevada in habitat types similar to those of the more common species. As fire cycles are restored to populations of these species, knowledge of Native American objectives for management of common Wyethia spp. and how Indians changed the frequency and intensity of fires may be integral to successful modern wildland management and restoration of these less common species.

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Comparative research on how natural resources were used, maintained, and influenced by different native groups in the Sierra Nevada is useful for developing objectives and methodologies for managing, conserving, and restoring wildlands (Anderson 1993a; Gomez-Pompa and Kaus 1992). Management of nature preserves and wilderness areas will have to involve continued human intervention. Land managers need to fully understand vegetation dynamics, including the role of disturbances (Sierra Nevada Research Planning Team 1994). Native peoples have to be recognized as a contributor to the

TABLE 9.3

Possible application of Native American use and management techniques for enhancement of uncommon, rare, or endangered plant species populations.

Uncommon, Rare, or Endangered Species	Other Species in Genus Known to Be Managed	Tribe	Part Used	Use	Management Techniques
Allium tribracteatum	Common *Allium* spp. (e.g., *Allium validum*)	Western Mono	Bulb	Food	Tilling/burning
Clarkia australis	*Clarkia purpurea* ssp. *purpurea*	Central Sierra Miwok	Seed	Food	Sowing/burning
Perideridia parishii ssp. *latifolia*	*Perideridia bolanderi; P. gairdneri; P. kelloggii; P. parishii*	Northern Hill Yokuts; Sierra Miwok; Western Mono	Tuber	Food	Tilling/burning
Trifolium barbigerum var. *andrewsii*	Common *Trifolium* spp.	Northern Hill Yokuts	Leaf	Food	Burning
Wyethia elata and *W. reticulata*	*Wyethia helenioides; W. mollis*	Western Mono	Seed	Food	Burning

dynamics of ecosystem development. Similar to fires and floods, the cultivation techniques and harvesting strategies of indigenous peoples were types of disturbances that contributed to changes in structure and function of the vegetation. Understanding their past role in vegetation dynamics requires knowledge of the diversity and complexity of protoagricultural, native land-management systems as well as the sophisticated, traditional lore upon which they are based (Soulé and Kohm 1989).

Some traditional wildland-management systems combine high species, structural, and temporal diversity, efficient nutrient cycling and energy flow, and intricate biological interactions. Such complexities have been selected over a long period in response to a wide array of cultural demands. These systems are essentially waiting to be "rediscovered" and analyzed (Anderson 1994).

Management and restoration of the Sierra Nevada for such objectives as protecting soil and water resources, maintaining wildlife habitat, and preserving biological diversity must be grounded in historical research and not rest on the illusion that the prehuman ecosystems are still intact and self-sustaining. Accurate reconstructions of interactions between native people and the natural environment in the Sierra Nevada and attempts to quantify the effects of indigenous horticultural practices on vegetation dynamics will require highly qualified, interdisciplinary teams of social, physical, and biological scientists working cooperatively with contemporary Native Americans in specific regions. Methodologies for collecting data would include oral interviews, archaeobotanical remains, and analysis of pollen, charcoal deposits, fire scar tree rings, museum artifacts, and written accounts, allowing for the independent cross-checking of conclusions (Crumley 1994). To date, these types of comprehensive studies are rare in the Sierra Nevada. One such study uses archaeological data, charcoal concentrations, and pollen cores to examine a long-term environmental change in Yosemite Valley (Anderson and Carpenter 1991). One of the biggest challenges will be to find more effective and creative ways to blend indigenous knowledge and scientific knowledge systems (DeWalt 1994). Native American experience with resource management of wildlands could be combined with theories of population biology and biogeography to develop new approaches and methods for preserving species (Primack 1993).

Future Research Priorities

To begin developing the information upon which innovative management strategies can be based, the following studies are recommended.

1. Determine whether fire and other vegetation-management methods used by Native Americans should be reintroduced. Set up a series of field experiments in the Sierra Nevada to simulate indigenous horticultural practices and harvesting strategies, and assess the interrelations and impacts of such cultural practices on individual plants, populations, communities, and ecosystem characteristics and dynamics.
2. Document knowledge systems of tribal elders. Conduct more in-depth ethnographic studies with Indian elders to ascertain details of former wildland-management practices in different plant-community types in the Sierra Nevada. Highest priority should be given to use patterns and knowledge systems that are disappearing most rapidly among the elder populations.
3. Reconstruct vegetation. Provide an accurate estimate of the understory plant species composition of late prehistoric forests in the Sierra Nevada using phytolith analysis, ethnographic interviews, early historical landscape descriptions, historical photographs, and early herbarium specimen collections.
4. Estimate indigenous populations. Develop a realistic prehistoric human-population estimate for the Sierra Nevada based upon early historical accounts, carrying-capacity estimates, archaeological site record analysis, land-use/settlement models, census data, and disease-spread models.
5. Investigate the significant prehistoric developments and their impacts. Measure and evaluate the ecological impacts of significant prehistoric developments—human entry, hunting (predation), reliance on acorns, use of bedrock mills, introduction of the bow and arrow, and exchange systems on the Sierra Nevada bioregion.
6. Calculate managed plant material quantities. Extrapolate from the numbers of adventitious shoots, flower stalks, and rhizomes needed for each basket type and herbaceous stems needed for each cordage item to the annual needs and landscape impacts for an average-sized village in three tribal territories in the Sierra Nevada.
7. Assess the importance of different plant species in historic basketry of tribes. Devise diagnostic features to accurately assess the identification of plant species used in the baskets of Sierra Nevada tribes in museum collections. Identify plant species used in different basket types. Rank the importance of plant species used in basketry by each tribe in the Sierra Nevada, and reconstruct major basketry complexes.
8. Assess the importance of different plant species in the historic diets of tribes. Reconstruct the major food complexes of different Sierran tribes through analysis of museum ethnobotanical collections, survey of existing literature, ethnographic interviews, and archaeological findings.

9. Document habitat loss of culturally significant plants. Inventory the native plant species that are useful to contemporary Native American cultures in the Sierra Nevada, and assess the habitat loss of culturally significant plants.

10. Compare life-history traits and habitat requirements of rare and endangered plant species and related common species (same genus) that were managed by Sierran tribes.

11. Investigate relationships between Native American economic practices and the faunas of the Sierra Nevada. Studies to date have emphasized Native American management of plant resources. Similar studies are needed to investigate the direct and indirect effects of traditional Native American economic practices on the nature and quantitative aspects of faunal assemblages in the Sierra Nevada.

12. Activate a regional study with an interdisciplinary team. Combine archaeological, ethnographic, paleoecological, fire-history, and museum research to yield a better understanding of the resource and management needs of prehistoric tribal villages in diverse Sierran localities. With this detailed information, it would be possible to better estimate the amount of "managed" acreage that would be needed to meet resource requirements of villages in the entire region over long periods of time.

Education, Planning, and Management Proposals

1. Establish an advisory council (or several regional councils), including Native Americans and specialists in such fields as ethnography, ethnobotany, ecology, archaeology, and ecosystems management, to assist land-managing and land-permit agencies in any general planning, zoning, and site development that could significantly affect Sierran ecosystems.

2. Recognize Indian-set fires as an integral disturbance factor in shaping Sierra Nevada ecosystems. Integrate intentional burning to simulate these former practices into overall land-use and fire-management planning.

3. Acknowledge the significance of pre-contact Native American land uses and fire-management regimes in local and regional planning and zoning, and discourage development in fire-type vegetation communities and other environmentally sensitive areas.

4. Establish traditional resource-use areas on public lands for access by Native Americans; such areas would be managed with sensitivity to traditional values.

5. Teach schoolchildren and the general public about Native American conservation ethics and traditional land-use and resource-management practices.

6. Create an ethnobiology handbook for public land managers in California that defines the field and its methodologies, major issues, research priorities, and relevance to ecosystem management and conservation biology.

7. Develop a geographic information system (GIS) database of temporally segregated archaeological site locations in the Sierra Nevada to permit modeling of past land-use patterns. Incorporate findings into modern land-use planning and zoning.

8. Systematically catalog ethnobotanical and ethnozoological information for each tribe in the Sierra Nevada into an ethnobiological database that would complement and interface with the existing Natural Diversity Data Base and SNEP's GIS.

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